

# **Functional Requirements for Development of Ground Facilities Supporting the Generic Transport Model**

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**Prepared by Roger M. Bailey**

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**GTM Ground Facilities Implementation Lead**

**Prepared by Richard M. Hueschen**

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**GTM Research Systems Development Lead**

## **Concurrences:**

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**Raymond S. Calloway**  
Head, ATB/AIRSC

---

**Plesent W. Goode**  
Acting Head, GCB/AIRSC

---

**Mark A. Hutchinson**  
Head, AMSSB/AAAC

---

**Christine M. Belcastro**  
CUPR/ GTM Project Technical Lead

---

**Celeste M. Belcastro**  
VHM&FCSD / GTM Project Technical  
Lead

---

**Vernon E. Watkins**  
GTM Project Manager

## Revision History

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0.1	2/17/04	Original Draft Issue
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# 1 Introduction

## 1.1 Scope

This document summarizes the functional requirements pertaining to the design, implementation and operation of the ground facilities hardware systems and subsystems being developed to support the Generic Transport Model (GTM) as part of the Airborne Subscale Transport Aircraft Research (AirSTAR) test bed project.

## 1.2 Background

The GTM is a 5.5% dynamically scaled model of a transport twinjet aircraft that is operated as a Remotely Piloted Vehicle (RPV). The GTM, as part of AirSTAR, will support focused research in Aviation Safety & Security, with primary emphasis on in-flight validation of flight control algorithms and safety enhancement systems involving high-risk conditions. The subscale vehicle flight test capabilities of the GTM will facilitate the study of advanced flight-controls research concepts including:

- Investigating technologies for preventing and recovering from control-upset conditions due to on-board failures, aircraft damage, pilot error, or external disturbances.
- Gathering aerodynamic data for off-nominal flight conditions (e.g. large angle-of-attack and sideslip conditions).
- Investigation of new aerodynamic technologies - for example, a new wing design.

Operation of the GTM will require ground support infrastructure including pilot controls, data telemetry, voice communications, tracking and computing resources. Due to the GTM's currently limited on-board computational capability, research flight control/management algorithms will be hosted in ground support computing resources.

## 1.3 Facilities Overview

The GTM Ground Facilities encompass the hardware and software infrastructure necessary to provide comprehensive support services for the AirSTAR test bed project. Support services will include activities ranging from subsystem development to integrated system check-out to conducting flight test experiments. The ground facilities will support remote piloting of the GTM aircraft, and include all subsystems required for data/video telemetry, experimental flight control algorithm development and implementation, GTM simulation, and audio communications. The ground facilities will include a self-contained, motorized vehicle serving as a mobile research command/operations center, capable of deployment to remote sites when conducting GTM flight experiments. The ground facilities will also include a laboratory based at NASA LaRC providing near identical capabilities as the mobile command/operations center, as well as the capability to receive data/video/audio from, and send data/audio to the mobile command/operations center during GTM flight experiments.

## 1.4 Acronyms, Abbreviations, and Definitions

AirSTAR	Airborne Subscale Transport Aircraft Research
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ARMOR	Asynchronous Real-Time Multiplexer and Output Reconstructor
BRS	Base Research Station
DGPS	Differential Global Positioning System
DMU	Digital Multiplexer Unit
DRU	Digital Recorder Unit
EADI	Electronic Attitude Director Indicator
EGPWS	Enhanced Ground Proximity Warning System
FDI	Failure Detection and Isolation
GPS	Global Positioning System
GTM	Generic Transport Model
GUI	Graphical User Interface
HUD	Heads Up Display
LaRC	Langley Research Center
MOS	Mobile Operations Station
NASA	National Aeronautics and Space Administration
PC	Personal Computer
PCM	Pulse Code Modulation
PI	Principal Investigator
R/C	Radio Controlled
RAID	Redundant Array of Inexpensive Disks
RPV	Remotely Piloted Vehicle
SAFETI	Systems and Airframe Failure Emulation Testing and Integration
SD	Strategic Display
TD	Tactical Display
TM	Telemetry
TSS	Tracking System Station
UPS	Uninterruptible Power Supply
UTC	Coordinated Universal Time

## 1.5 Facilities Description

The GTM Ground Facilities will be designed and developed to support the AirSTAR test bed project, and will be comprised of two elements:

- 1) A Mobile Operations Station (MOS) to be used at remote sites to fly the GTM during the conduct of flight control, aerodynamic, flight dynamics, and other research flight experiments.
- 2) A Base Research Station (BRS) at LaRC for flight experiment algorithm development, hardware-in-the-loop simulation, pilot training, and piloted simulation of flight experiments prior to flight, and monitoring/observation during flight experiments.

The MOS will transmit commands to and receive data and camera video from the GTM, provide the means to control the GTM, monitor its dynamic state, performance, and position within a specified flight test area, and provide video tracking of the GTM. The GTM will be manually flown through the MOS via a side-stick controller or automatically via control laws in a ground-based computer. The GTM can be manually flown via a hobbyist R/C box for takeoff and landing, for flights to checkout onboard instrumentation and for safety backup intervention.

A Principal Investigator (PI) for each flight experiment will be responsible for developing experiment-specific algorithms for implementation in the ground computer and/or flight test scenarios (i.e. implementation and check-out in the BRS and eventual flight in the MOS).

## 2 Functional Requirements

### 2.1 MOS/BRS Common Requirements

The BRS will be installed in LaRC's SAFETI Lab and the MOS will be installed into a suitable vehicle for deployment to remote test sites. The BRS and MOS shall be nearly functionally identical, however, the BRS will be used for subsystem development, checkout and integrated system testing during preparations for flight tests. Equipment compatibility shall exist between the MOS and BRS through use of identical hardware as much as practicable.

#### 2.1.1 Pilot Controls

Ground facilities shall provide a sidestick controller, rudder pedals, throttle, and other necessary input devices to allow the research pilot to fly the GTM. Provision shall be made to integrate an appropriate R/C control box to allow the safety pilot to fly the GTM. The R/C box shall provide the exclusive capability to select whether R/C control (safety pilot) or MOS (research pilot) control is active.

#### 2.1.2 Computational Resources

GTM ground-based computational resources shall:

- a) Be capable of processing, in real-time, PI provided algorithms, including but not limited to:

- flight control algorithms to compute control-surface and engine commands in response to pilot inputs and/or aircraft state data
  - failure detection and isolation (FDI) algorithms, upset recovery algorithms, and guidance algorithms
- b) Be capable of (1) receiving TM GTM state data (e.g. sensor outputs, discretes, etc.) and converting these data to calibrated engineering units in real-time, and (2) transmitting control-surface and engine commands and other GTM state data to the GTM via the TM system
- c) Provide for the storage, archiving and post-flight retrieval/playback of pertinent flight test data, including but not limited to:
- pilot time histories of pilot inputs
  - control-surface and engine commands
  - GTM TM data
  - selected control-law internal parameters
- d) Provide real-time, hardware-in-the-loop simulation of the GTM, and shall include the capacity for integrating synthetic vision display components and terrain databases
- e) Provide a Graphical User Interface (GUI) that will allow the PI to set experiment parameters
- f) Be compatible with appropriate engineering development environments including but not limited to Matlab, Simulink, and Real-Time Workshop
- g) Provide expansion capability to allow addition of more computational power

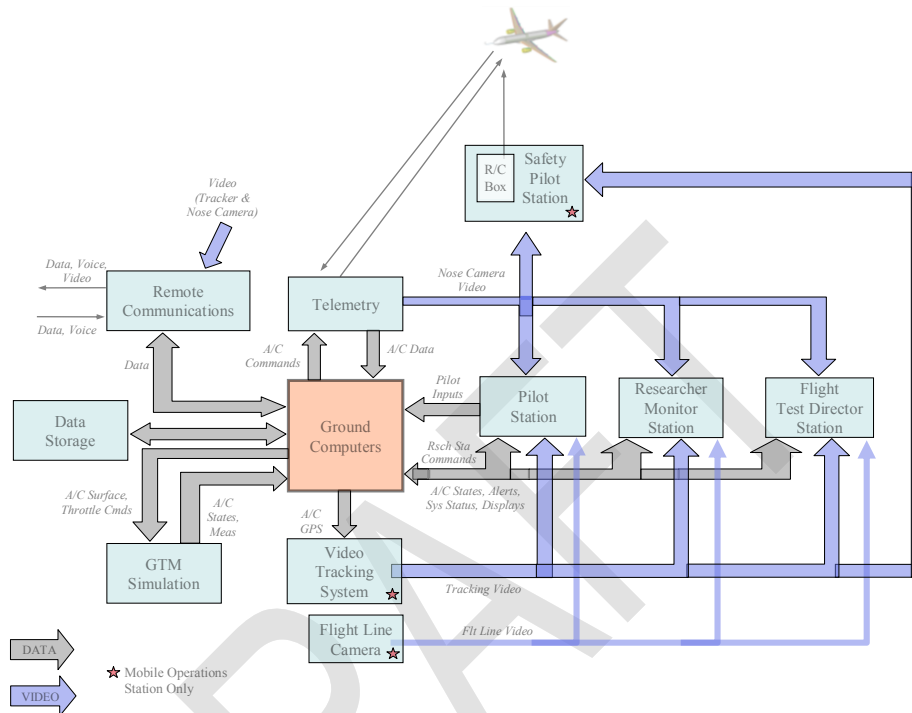
### **2.1.3 Displays**

The GTM ground facilities shall provide for the development, generation and distribution of appropriate graphical displays for the research pilot, the flight test director and the PI, including, but not limited to, the following data/information:

- any available GTM state data and/or experiment parameters
- camera video (i.e. tracking system, GTM nose camera, other on-board and ground-based cameras)
- Tactical and Strategic Displays (TD and SD) incorporating elements similar to those typically presented as part of the Electronic Attitude Director Indicator (EADI) systems found on modern commercial and business aircraft
- any available health and/or status information associated with the GTM and the ground facilities subsystems (e.g. on-board battery power, TM link signal strength, tracking system, etc.)

### **2.1.4 Expansion**

The GTM ground facilities shall be designed and developed so that baseline capabilities can be expanded and improved by upgrading existing subsystems and/or integrating new subsystems (e.g. adding an Enhanced Ground Proximity Warning System (EGPWS) ).



**Figure 2.1-1 Block Diagram of Ground Facilities Functionality**

Figure 2.1-1 above shows a conceptual block diagram of the BRS and MOS baseline architecture. Additional details regarding the functional requirements of the elements in the block diagram are provided in the following sections.

### 2.1.5 Pilot Station

This station provides the means to fly the GTM manually or automatically by engagement of a Principal-Investigator-provided autopilot flight control system implemented in the Ground Computer. The Pilot Station shall:

- a) Provide a side stick controller with programmable force feedback
- b) Provide rudder pedals with programmable force feedback
- c) Provide a Tactical Display (TD) including a Heads-Up Display (HUD)
  - shall be programmable to allow various experimental pilot displays and alerts to be evaluated

**Comment [RMB1]:** Fr Rob Rivers  
Roger and John,

I made a real quick look at the Pilot Station section of the Req Doc for the GTM and I had a couple of comments. On the description of the sidestick and rudder pedals, could we add "programmable" to the force feedback requirement. I think we may need to do a little tweaking to get the breakouts, gradients, etc. right. In the displays section, could we add a requirement for a programmable HUD. I believe in the meeting last week that we essentially decided on that based on the interface with the SVS folks, but it might be good to require one anyway. I am working on a notional first cut drawing of a simple HUD to give to John shortly for his take.

Hope this is of some use,

- a Primary Flight Display (PFD) and a Head's Up Display (HUD) are examples of a TD
- d) Provide a Strategic Display (SD)
  - shall be programmable to allow various experimental pilot displays and alerts to be evaluated
  - a navigation display would be an example of a SD
- e) Provide status displays
  - shall be programmable to allow various experimental pilot displays and alerts to be evaluated
- f) Provide a pilot GUI
  - the pilot GUI shall allow for selection of TD/SD configuration (e.g. select TD background to be nose-camera video, standard horizontal horizon display, or synthetic Out-The-Window display), side-stick and rudder pedal controller gains, and information to be displayed on the TD and SD
  - shall be programmable to allow various experimental pilot displays and alerts to be evaluated
- g) Provide access to all video camera outputs available during research flights (e.g. nose camera video, tracking video)
- h) Provide appropriate control switches
  - control switches shall be used for stabilizer, aileron, and rudder trim
  - control switches shall also be used to raise and lower the landing gear, engage/disengage autopilot control, auto throttle control, select engine cutoff, and command horizontal stabilizer flip-tail engagement (used for stall-recovery or mission abort)
- i) Provide a throttle control device
- j) Provide a braking control device
- k) Be comprised of the preceding components, arranged in a pilot acceptable layout
- l) Provide isolated two-way audio communication with the Flight Test Director Station and the R/C Safety Pilot Station

#### **2.1.5.1 Side Stick Controller**

A side stick controller shall be used by the pilot to manually command GTM movement about the longitudinal and lateral axis (roll and pitch). This controller shall be a high fidelity controller with programmable force feedback.

#### **2.1.5.2 Rudder Pedals**

Rudder pedals shall be used to manually command GTM movement about the vertical axis (yaw). This controller shall be a high fidelity controller with programmable force feedback.

### 2.1.5.3 Tactical Display (TD)

The TD will serve as the pilot's primary indicator of flight information; and shall provide GTM flight information, including but not limited to, attitude and heading, airspeed, altitude, track angle, flight path angle, load factor, angle-of-attack, and sideslip angle. The TD shall:

- Incorporate display elements typically presented as part of the Primary Flight Display (PFD) found on modern commercial and business aircraft
- Provide for inclusion of a programmable Heads-Up Display (HUD) for the research pilot. A HUD is an electronically generated display of flight, navigational, or other data superimposed upon the research pilot's forward field of view as represented on the TD
- Be capable of integrating synthetic Out-The-Window information or nose camera video into its background. The choice of background shall be selectable by the research pilot
- Be programmable to allow the display of research information (e.g. upset alerts and recovery cues)

Figure 2.1-2 shows an example of a potential TD display format with a synthetic vision background. Figure 2.1-3 shows an example of a potential GTM HUD format.

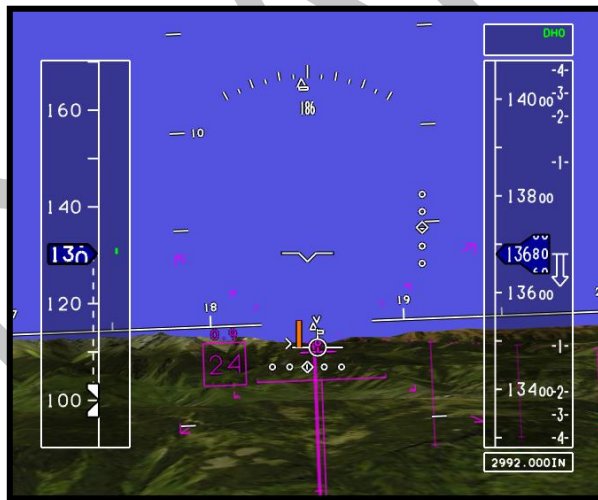


Figure 2.1-2 Proposed Tactical Display for GTM Ground Station

#### Comment [RMB2]: Fr Robb Myer

Roger

Thanks. This is the first opportunity I've had to see the big picture of the project. Two suggestions. Replace references to PFD and EADI with "Tactical Display" since will also be using a HUD, and "Strategic Display" since our display is more like a multi function display more than a ND. Also recommend you use the same icons and naming convention for all the diagrams.



**Figure 2.1-3 Example of HUD Concept for Research Pilot Station**

#### **2.1.5.4 Strategic Display (SD)**

The SD will serve as the pilot's primary indicator of the GTM's location during flight tests. The SD shall:

- a) Display a test range map about the vehicle location and the map shall include a runway depiction
- b) Provide vehicle location information on the map, including but not limited to:
  - vehicle track angle
  - desired horizontal path waypoints
  - path connecting the waypoints
  - predicted path in the next TBD time period (e.g. in the next 60 seconds)
  - the boundaries of the test range

Figure 2.1-4 shows an example of a potential SD format.

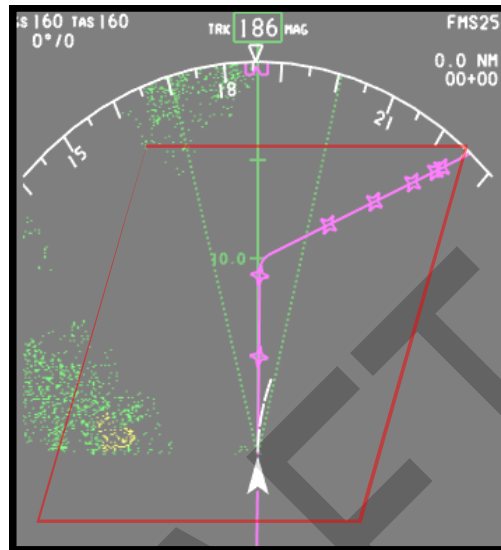


Figure 2.1-4 Example of Strategic Display Concept for GTM Ground Station

#### 2.1.5.5 Vehicle Nose Camera Video

An on-board Microwave-Band transmitter transmits the video output from the nose camera to the ground station. GTM ground facilities shall provide the capability to display this video on the TD.

**Comment [rmb3]:** Per Mike Norman, may need to carefully consider color, FOV and aperture control

#### 2.1.6 Flight Test Director Station

This station will be used by the Flight Test Director, who has the responsibility of coordinating all flight test-related activities. The Flight Test Director Station shall:

- Provide information for the flight test director to assess the progress of the testing, status of the test vehicle, and safety of the flight test
- Provide a display that will provide system status parameters, GTM states, and health parameters for the airborne vehicle
- Provide access to all computer generated displays and video camera outputs available during research flights (e.g. TD, SD, nose camera video)
- Provide for monitoring and control of all audio communications between MOS research stations, Video Tracking System operator, Safety pilot, and any other flight test participants deemed necessary

- e) Provide for display of data generated by the portable weather station and/or internet-based commercial weather products (e.g. regional radar, weather condition forecasts, etc)

### **2.1.7 Researcher Monitor Station**

The Researcher Monitor Station will be used by a Principal Investigator/Researcher to monitor the flight experiment and to perform post-flight analysis of the recorded flight data. The Researcher Monitor Station shall:

- a) Provide a Test Parameters Display. This display will provide test parameters that are selected by means of a GUI on this display. The GUI will provide the means to select computer-generated commands (e.g. doublet control surface commands), set discretes that control test conditions, and set simulated fault conditions. The display will provide the capability to provide information digitally and as time histories
- b) Provide access to all computer generated displays and video camera outputs available during research flights (e.g. TD, SD, nose camera video)
- c) Provide the capability to process and plot in real-time up to 20 selected parameters for monitoring by the research engineer
- d) Provide the capability to process, display and plot<sup>1</sup> stored data post-flight
- e) Provide the capability to produce paper reproductions of the data plots
- f) Provide the capability to run real-time analysis software if desired by the Principle Investigator
- g) Provide the capability of running the GTM simulation for pre/post-flight analysis
- h) Provide for audio communication with any other flight test participants deemed necessary

### **2.1.8 Telemetry (TM) System**

The telemetry system will provide a real-time, duplex data interface between the GTM and the MOS and a near-real-time, duplex data interface between the GTM and the BRS. Data transmitted to the GTM (TM uplink) shall command control of the vehicle flight. Data received from the vehicle (TM downlink) shall be sensor data and nose-camera video. The sensor data shall be used to drive the EADI and ND displays and as feedback data by research flight control, FDI, upset recovery, and guidance algorithms. The received data shall also be stored for post flight analysis of the research experiments. The TM system will be comprised of the necessary microwave band transmitters, receivers, and antennas plus the required data-processing interfaces. The TM system must operate without loss of positive control at MOS/BRS-to-GTM slant ranges up to 1 statute mile

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<sup>1</sup> X-Plot and QuickPlot are examples of plotting software that can meet this requirement and are compatible with Dryden Flight Research Center's compressed formats .cmp3 and .cmp4

The TM system maximum data rate shall be at least 216Hz. Data-rate requirements are based on maximum command and sensor rates of 40 – 50 Hz for a large twin-engine transport. Since the GTM flight dynamic response is a factor of approximately 4.25 faster than the full-scale airplane, these rates translated to a maximum data rate exceeding 200 Hz.

#### **2.1.8.1 Data Transmitted from MOS/BRS to GTM (TM uplink)**

Data is uplinked on L-band frequency 1835.5 MHz that is the Radio Frequency Authorization approved for GTM by the LaRC Radio Frequency Manager. The uplinked data shall consist of GTM surface commands, throttle commands, gear command, brake command, engine shutoff commands, and engine mode commands. The uplinked data is specified in Table 2.1-1, along with the required update rate, range, resolution, and polarity.

#### **2.1.8.2 Data Received at MOS/BRS from GTM (TM downlink)**

Data is downlinked on S-band frequency 2240.5 MHz that is the Radio Frequency Authorization approved for GTM. The downlinked data shall include measurements of vehicle attitudes, attitude rates, accelerations, Global Positioning System (GPS) and/or Differential Global Positioning System (DGPS) position, GPS velocity, barometric altitude, airspeed, angle of attack, sideslip angle, engine RPM, and surface positions. The downlinked data is specified in Table 2.1-2, along with the required update rate, range, resolution, and polarity. Additional downlinked data not shown in Table 2.1-2 shall include vehicle subsystem status data and discretes (e.g., engine control unit data, battery voltage monitoring data, and landing gear strut position).

Video downlink capability shall be compatible with the GTM nose-camera video signal.

**Table 2.1-1 Required Uplink Data Specifications<sup>2</sup>**

Data	Mnemonic	Rate , Hz <sup>3</sup>	Range	Resolution	Polarity	Comment
1. Left OB aileron command	AILLOBC	200	± 30 deg	0.05 deg	+ TED	
2. Left IB aileron command	AILLIBC	200	± 30 deg	0.05 deg	+ TED	
3. Right OB aileron command	AILROBC	200	± 30 deg	0.05 deg	+ TED	
4. Right IB aileron command	AILRIBC	200	± 30 deg	0.05 deg	+ TED	
5. Left OB spoiler command	SPLLOBC	200	0 to 60 deg	0.05 deg	always pos	
6. Left IB spoiler command	SPLLIBC	200	0 to 60 deg	0.05 deg	always pos	
7. Right OB spoiler command	SPLROBC	200	0 to 60 deg	0.05 deg	always pos	
8. Right IB spoiler command	SPLRIBC	200	0 to 60 deg	0.05 deg	always pos	
9. Left OB elevator command	ELLOBC	200	-45 to +30 deg	0.05 deg	+ TED from stab CP	CP is chord plane
10. Left IB elevator command	ELLIBC	200	-45 to +30 deg	0.05 deg	+ TED from stab CP	
11. Right OB elevator command	ELROBC	200	-45 to +30 deg	0.05 deg	+ TED from stab CP	
12. Right IB elevator command	ELRIBC	200	-45 to +30 deg	0.05 deg	+ TED from stab CP	
13. Upper rudder command	RUDUPC	200	± 45 deg	0.05 deg	+ TEL	
14. Lower rudder command	RUDLOC	200	± 45 deg	0.05 deg	+ TEL	
15. Stabilizer command	STAB	40	-20 to +10 deg	0.05 deg	+ TED from FRL	FRL is fuselage reference line
16. Left OB flap command	FLAPLOC	40	0 to 45 deg	0.05 deg	always pos	
17. Left IB flap command	FLAPLIC	40	0 to 45 deg	0.05 deg	always pos	
18. Right OB flap command	FLAPROC	40	0 to 45 deg	0.05 deg	always pos	
19. Right IB flap command	FLAPRIC	40	0 to 45 deg	0.05 deg	always pos	
20. Left throttle command	THROTL	100	0 to 100%	0.1 %	always pos	
21. Right throttle command	THROTR	100	0 to 100%	0.1 %	always pos	
22. Gear command	GEARC	1	0 to 100%	1 %	0 up, 100 down	
23. Brake command	BRAKEC	40	0 to 100%	0.1 %	always pos	
24. Nose gear steering command	STEERC	20	± 30 deg	0.1 deg	+ turn right	
25. Horizontal flip tail command	STABFTC	10	0 to 90 deg	1.0 deg	+ TED	
26. Fuel Shutoff - left engine	FUELSOL	2	0 to 1	integer		
27. Fuel Shutoff - right engine	FUELSOR	2	0 to 1	integer		
28. Engine mode left	ENGMODL	2	0 to 2	integer		
29. Engine mode right	ENGMODR	2	0 to 2	integer		
30. Spare variable 1	SPARE1	40	0 to 1	0.1 %		
31. Spare Discrete 1	DISC1	1	NA			

<sup>2</sup> Note that satisfying these requirements is driven much more by onboard sensing quality (where all three parameters are really set) than by telemetry system whose resolution by far surpasses these needs. Effecting high-fidelity mechanical readouts will be general limiting factor.

<sup>3</sup> Note that these are minimum rate requirements. The delivered rates from the telemetry commutator actually exceed these values (sometimes by a large margin due to data packaging tradeoffs). Note that delivered rates specifically are {216, 108, 54, 27} Hz

**Table 2.1-2 Required Downlink Data Specifications<sup>45</sup>**

Data	Mnemonic	Rate , Hz <sup>6</sup>	Range	Resolution	Polarity	Comment
1. Roll attitude <sup>7</sup>	ROLL	250	± 180 deg	0.01 deg	+ Rt. wing down	
2. Pitch attitude	PITCH	250	± 90 deg	0.01 deg	+ nose up	
3. True heading	YAW	100	±180 deg	0.01 deg	+ rt of true north	
4. Body roll rate	PB	250	±315 deg/sec	0.01 deg/sec	+ rt wing down	
5. Body pitch rate	QB	250	±170 deg/sec	0.01 deg/sec	+ nose up	
6. Body yaw rate	RB	250	±126 deg/sec	0.01 deg/sec	+ nose right	
7. CG X body acceleration	AXCG	250	± 10 g	0.01 g	+ inertial spd incr	
8. CG Y body acceleration	AYCG	250	± 10 g	0.01 g	+ to right	
9. CG Z body acceleration	AZCG	250	± 10 g	0.01 g	+ down	
10. vane angle of attack	ALPHAV	80	± 90 deg	0.05 deg	+ vane TEU	
11. vane sideslip	BETAV	80	± 90 deg	0.05 deg	+ vane TEL	
12. Calibrated airspeed	CAS	40	10 to 200 knots	0.1 knots	always pos	
13. GPS latitude <sup>8</sup>	LATGPS	20	0 to 90 deg	10 <sup>-6</sup> deg	+ above equator	Resolution equivalent to 0.364 ft at equator
14. GPS longitude	LONGPS	20	-180 to 0 deg	10 <sup>-6</sup> deg	+ east Greenwich	Resolution equivalent to 0.364 ft at equator
15. GPS altitude	ALTGPS	100	0 to 5000 ft	0.5 ft	+ above ellipsoid	
16. GPS ECEF x velocity		20	± 200 ft/sec	0.5 ft/sec		Earth Centered Earth Fixed (ECEF) axes
17. GPS ECEF y velocity		20	± 200 ft/sec	0.5 ft/sec		
18. GPS ECEF z velocity		20	± 200 ft/sec	0.5 ft/sec		
19. Barometric altitude	ALTBARO	100	0 to 5000 ft	1 ft	+ above MSL	
20. Left engine RPM	RPML	20	0 to 160,000 RPM	1000 RPM	always pos	
21. Right engine RPM <sup>9</sup>	RPMR	20	0 to 160,000 RPM	1000 RPM	always pos	
22. Left OB aileron position	AILLOB	200	± 30 deg	0.05 deg	+ TED	
23. Left IB aileron position	AILLIB	200	± 30 deg	0.05 deg	+ TED	
24. Right OB aileron position	AILROB	200	± 30 deg	0.05 deg	+ TED	
25. Right IB aileron position	AILRIB	200	± 30 deg	0.05 deg	+ TED	
26. Left OB spoiler position	SPLLOB	200	0 to 60 deg	0.05 deg	always pos	

<sup>4</sup> Note that a number of designed/delivered low rate signals (e.g. voltage monitors, gear, and other logical reads) do not actually appear in the requirements of this table

<sup>5</sup> Note that satisfying these requirements is driven much more by onboard sensor quality (where all three parameters are really set) than by telemetry system whose resolution by far surpasses these needs. Effecting high-fidelity mechanical readouts will be general limiting factor

<sup>6</sup> Note that these are minimum rate requirements. The delivered rates from the telemetry commutator actually exceed these values (sometimes by a large margin due to data packaging tradeoffs). Note that delivered rates specifically are {216, 108, 54, 27} Hz. FURTHERMORE note that group consensus degraded the required rate of 250 Hz due to telemetry data packaging constraints. Thus, whenever it is seen in this column, it is implicitly understood to represent the smaller value to 200 Hz.

<sup>7</sup> Note that these three INS quantities (rows 1-3) are not available from the MIDG (present equipment) as it is being operated in IMU mode due to engineering constraints. Group was made aware of this compromise and received suggestion to effect this INS integration in ground real-time computer

<sup>8</sup> Note that these six GPS quantities (rows 13-18) are only available at a rate of 1 Hz with present equipment. Group was informed of this compromise and received a suggestion of moving to a more capable unit with 10 Hz rate (approximately 4 k\$ plus engineering costs)

<sup>9</sup> Note that the GTM commercially available (as opposed to custom) engine control units, though being feed at a satisfactory rate, only have the (estimated) capability to work at a 6 Hz rate.

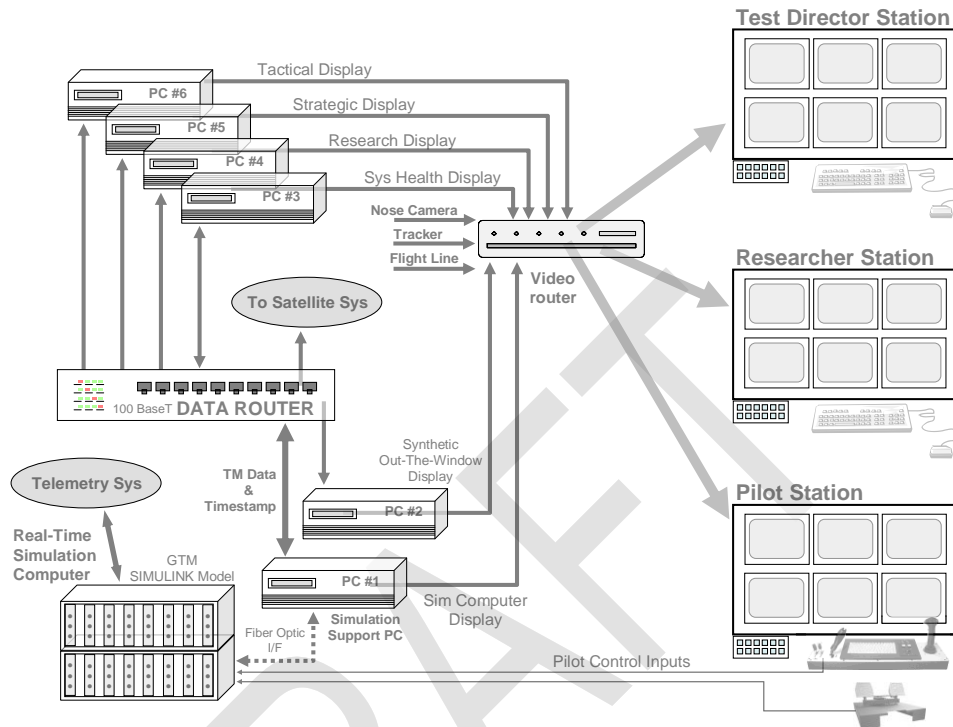
27. Left IB spoiler position	SPLLIB	200	0 to 60 deg	0.05 deg	always pos	
28. Right OB spoiler position	SPLROB	200	0 to 60 deg	0.05 deg	always pos	
29. Right IB spoiler position	SPLRIB	200	0 to 60 deg	0.05 deg	always pos	
30. Left OB elevator position	ELLOB	200	-45 to +30 deg	0.05 deg	+ TED from stab CP	CP is chord plane
31. Left IB elevator position	ELLIB	200	-45 to +30 deg	0.05 deg	+ TED from stab CP	
32. Right OB elevator position	ELROB	200	-45 to +30 deg	0.05 deg	+ TED from stab CP	
33. Right IB elevator position	ELRIB	200	-45 to +30 deg	0.05 deg	+ TED from stab CP	
34. Rudder upper position	RUDUP	200	± 45 deg	0.05 deg	+ TEL	
35. Rudder lower position	RUDLOW	200	± 45 deg	0.05 deg	+ TEL	
36. Stabilizer position	STAB	40	-20 to +10 deg	0.05 deg	+ TED from FRL	FRL is fuselage reference line
37. Left OB flap position	FLAPOBL	40	0 to 45 deg	0.05 deg	always pos	
38. Left IB flap position	FLAPIBL	40	0 to 45 deg	0.05 deg	always pos	
39. Right OB flap position	FLAPOBR	40	0 to 45 deg	0.05 deg	always pos	
40. Right IB flap position	FLAPIBR	40	0 to 45 deg	0.05 deg	always pos	
41. X body acceleration, E1	AXE1	250	±32 ft/sec <sup>2</sup>	0.03 ft/sec <sup>2</sup>	+ wing tip forward	E1 & E2 accelerations for Bart Bacon experiment
42. Y body acceleration, E1	AYE1	250	±32 ft/sec <sup>2</sup>	0.03 ft/sec <sup>2</sup>	+ to right	
43. Z body acceleration, E1	AZE1	250	±120 ft/sec <sup>2</sup>	0.03 ft/sec <sup>2</sup>	+ down	
44. X body acceleration, E2	AXE2	250	±32 ft/sec <sup>2</sup>	0.03 ft/sec <sup>2</sup>	+ tail forward	
45. Y body acceleration, E2	AYE2	250	±32 ft/sec <sup>2</sup>	0.03 ft/sec <sup>2</sup>	+ to right	
46. Z body acceleration, E2	AZE2	250	±120 ft/sec <sup>2</sup>	0.03 ft/sec <sup>2</sup>	+ down	

### **2.1.9 Ground Computers**

The ground-based computing resources shall provide the capability to achieve the following in real-time:

- a) Execute the Principal-Investigator-provided control-law, FDI, guidance, upset recovery, and pilot cueing algorithms
  - the ground computer will have software and compilers to compile and execute PI algorithms that are provided in Matlab, Simulink, C, or Fortran source code
  - these algorithms will require execution update rates exceeding 200 Hz.; the appropriate ground computer shall support compilation and execution of these codes
  - the appropriate ground computer shall provide minimum storage space of 40GB
- b) Provide I/O processing to input the measurements from the GTM downlink receiver and pilot station commands and to output PI algorithm and pilot station commands to the GTM uplink transmitter. The I/O processing must handle downlink measurement rates of at least 216 Hz and PI algorithm uplink commands of at least 216 Hz. The I/O processing must handle pilot station input command rates of at least 30 Hz. The I/O processing shall output the measurements and data to display computers at rates of at least 30 Hz
- c) Export archival data to data storage
- d) Generate displays required for the Flight Test Director, Researcher and Pilot Stations, including synthetic vision displays based on terrain data processing
- e) Employ Coordinated Universal Time (UTC) time code stamping for data and displays

Figure 2.1-5 shows a conceptual diagram of the MOS/BRS baseline network architecture for data and video.



**Figure 2.1-5 Data/Video Network Architecture for MOS/BRS Ground Computers**

### **2.1.10 Data Collection and Storage**

Integral to the mission of AirSTAR scientific research are data collection and storage. In having a primary emphasis on in-flight validation of control algorithms involving high-risk/off-nominal conditions the effort of flight due to setting up such conditions is nontrivial. Thus, it is crucial to overall scientific throughput that the collection process be efficient and reliable. The success of post-flight research hinges on the accurate and properly registered capture of the air vehicle state and the ground system process. With valid and complete data the stated goals of investigating new aerodynamic technologies can be more fully realized.

Towards the successful preservation of experiment flight results through the generation of record data the GTM ground station shall be equipped with formal recording/reproducing capabilities that include the following design characteristics:

- a) This system capability shall be formed around an Asynchronous Real-Time Multiplexer and Output Reconstructor (ARMOR) subsystem. This system element consists of a Digital Multiplexer Unit (DMU) and a Digital Recorder Unit (DRU) that act in concert together to provide high-speed recording/playback of a mixture of asynchronous signals while preserving timing coherency

- b) The DMU shall be optioned through plug-in card capability to support input/output signals among a wide variety of low/high rate data types that include Pulse Code Modulation (PCM), Video, Digital, Analog, and Coordinated Universal Time (UTC) formats
- c) The aircraft uplink/downlink streams shall be sampled on the ground at the point of modulation/demodulation outside of the main real-time computer to serve as master copies of the command/sensor loop telemetry
- d) Time histories of the uplink/downlink telemetry streams shall be recorded at minimum aggregate rates of 2 Mb/s. Component data may also be recorded at maximum rates of 250 Hz as an option for flexibility
- e) This ARMOR system shall be configured within the MOS through the use of appropriate signal switchgear to provide playback as well as recording of all GTM flight data parameters, physical camera video outputs, synthetic display video outputs, audio loops, and UTC tag information
- f) If possible interfacing can be achieved, then inclusion shall be made in recording for weather station (i.e. wind speed and temperature) data as well. Playback can be limited to a simple CRT display capability versus be implemented on the station itself
- g) Versatility shall be effected within ARMOR playback to allow either complete data reconstruction or to allow partial data reconstruction
- h) Complete data reconstruction shall feed all CRT displays, instruments, and audio loops with mission data as presented by the DRU without the running of a real-time simulation. Uplink telemetry shall be available as a feed to the aircraft. Complete reconstruction provides an exact “as-it-happened” mission view including any possible anomalies within the entire air-ground system
- i) Partial data reconstruction shall feed only downlink telemetry, physical camera video, audio loops, and master UTC information from the DRU so as to allow the running of new real-time simulations upon old state data. Partial reconstruction provides a one-sided “make-it-happen” mode to allow further engineering of the air-ground system and importantly to allow debugging of anomalous behavior
- j) The DTU shall be sized to allow recording at a sustained total rate of approximately 100 Mb/s for a minimum of 60 minutes. The mode of storage shall be in hard drive media preferably implemented in a Redundant Array of Inexpensive Disks (RAID) configuration towards affording protection of flight data against loss. These disks media shall exist in the form of removable packs to allow swapping between tours and/or missions
- k) An accessory tape drive and DVD recorder, either internal or external to the ARMOR system, shall be provided for copying select mission files
- l) Data variables to be recorded, up to a maximum of 300, and the recording rate shall be programmable
- m) All video camera outputs and computer generated display outputs shall be recorded along with a time stamp
- n) All data, including video, shall be synchronized for post flight analysis and reconstruction

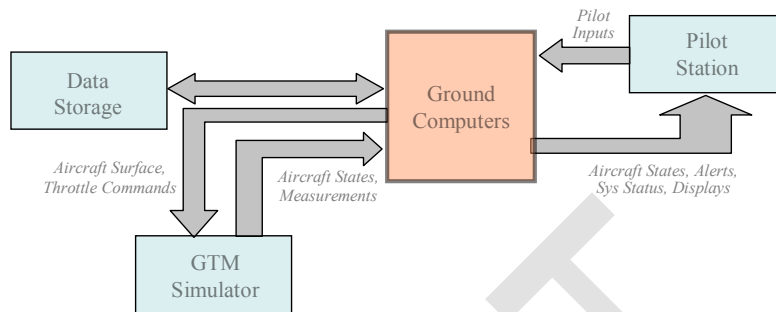
- o) Data shall be stored in a format compatible with plotting software to be provided as part of the Ground Station. Dryden Flight Research Center's compressed formats .cmp3 and .cmp4 are examples of data formats that might meet the requirements

### **2.1.11 GTM Simulator**

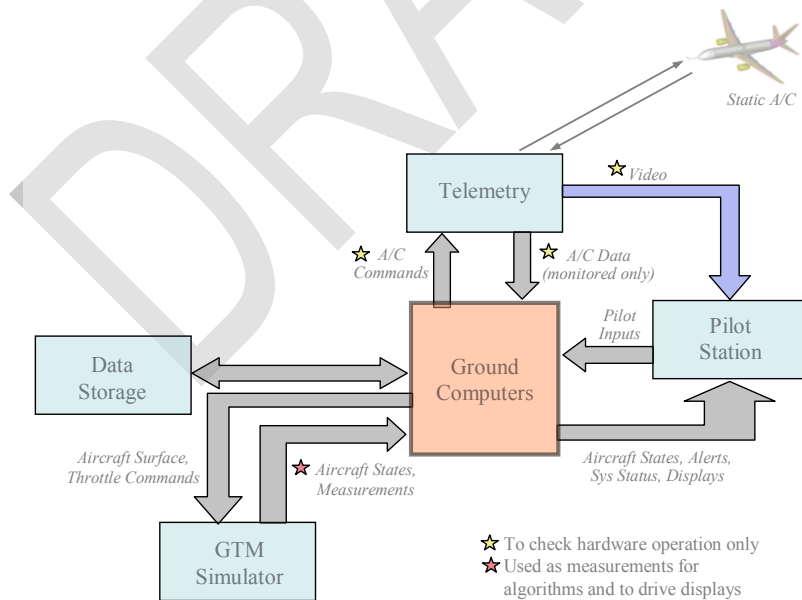
The GTM simulator is a software simulation of the GTM written in Matlab/ Simulink, including Matlab S-functions written as Matlab m-functions or C-Mexfiles. The GTM software simulation can be hosted on a Simulation Computer or on the Ground Computer if the Ground Computer capabilities are sufficient for simultaneously providing the Ground Computer and GTM Simulator functions

In the piloted simulation mode shown in figure 2.1-6, the GTM Simulator is used as a piloted simulator without the telemetry system and the GTM. All GTM functions are software simulated. This mode will be used for algorithm development, pilot training, and pilot familiarization with the research maneuvers.

In the hardware-in-the-loop mode shown in figure 2.1-7, aircraft dynamics and sensor measurements (output from GTM Simulator block in figure 2.1-7) will be software simulated just as in the piloted simulation mode. However, all aircraft commands (output from Ground Computer block to Telemetry block of figure 2.1-7) will be telemetered to the GTM in the laboratory, and GTM sensor outputs (output from Telemetry block to Ground Computer block in figure 2.1-7) will be telemetered back to the Ground Station to validate proper hardware operation. The aircraft data will only be monitored and not used in any control command calculations since the aircraft will be stationary.



**Figure 2.1-6 Piloted Simulation Configuration**



**Figure 2.1-7 Hardware-In-The-Loop (HIL) Simulation Configuration**

## 2.2 MOS-Specific Requirements

### 2.2.1 Vehicle

#### 2.2.1.1 Vehicle Description

The purpose of the MOS is to provide a reliable, rugged, self-propelled, self-contained, ground support facility for GTM test flight operations.

- a) The MOS shall contain all the necessary subsystem components to meet or exceed the GTM ground facilities requirements described in section 2.1 (***MOS/BRS Common Requirements***) of this document
- b) The MOS shall contain all ancillary support subsystems required for operation in the field, including, but not limited to:
  - a power generator
  - UPS back-up subsystem
  - restroom facility
  - kitchenette (incl. sink, refrigerator, microwave)
  - small meeting/work area
  - walk-on roof with safety rails
  - leveling jacks.

#### 2.2.1.2 Mobility

The MOS shall be a fully mobile, self powered, vehicle with the ability to navigate normal roadway terrain and level compacted grass/dirt fields.

#### 2.2.1.3 Drivability

- a) The MOS may be in a weight class requiring special driver/operator endorsements. Only licensed drivers with the proper endorsements shall operate the MOS.
- b) The MOS vehicle shall be drivable under Department Of Transportation (DOT) and state regulations
- c) The MOS shall be capable of being operated on the interstate highway system and other state roadway systems

#### 2.2.1.4 External Interfaces

The MOS shall provide external power and data interfaces for the following subsystems:

- a) Safety Pilot Station
- b) Wireless receivers for Tracking video and Flight Line video
- c) Wireless transmitter for GPS data
- d) VHF and cellular communications devices

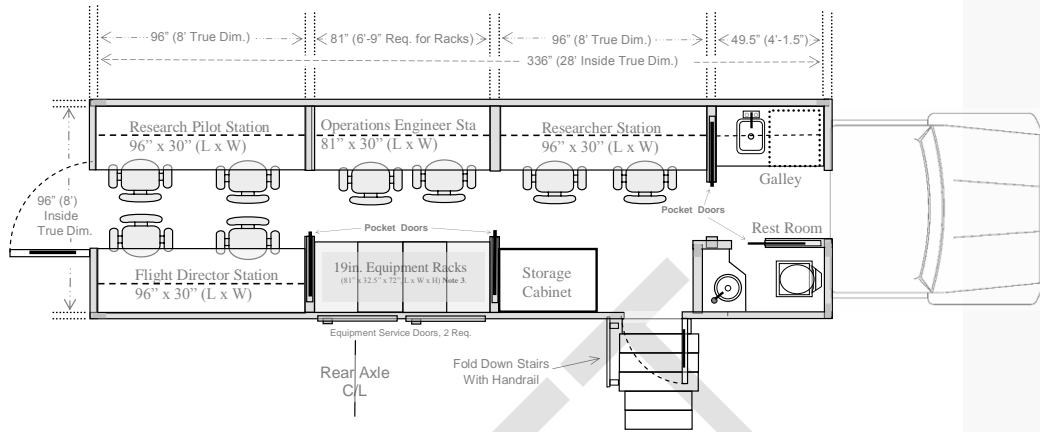
- e) LAN/internet
- f) Portable satellite dish
- g) 120VAC “Shore” power feeds

#### 2.2.1.5 Performance

The MOS vehicle shall be a self-powered unit capable of storing, transporting, and operating equipment and supplies required to support GTM flight test operations in the field. The MOS vehicle shall:

- a) Contain a combustion engine that operates on gasoline or diesel fuels
- b) Have a minimum of two front seats, a driver and passenger.
- c) Contain a minimum of one 120VAC generator with a capacity of at least TBD watts.
  - The generator shall be mounted on slide rail system to allow for operation outside the storage compartment and required maintenance routines.
- d) Be equipped with a portable weather station with data display interface to the Flight Test Director Station
- e) Be equipped with an environmental control unit capable of maintaining the work station area temperature to operational levels of the electronic equipment (within a range of 50F to 80F)
  - the environmental control unit shall be powered by 120VAC
  - a variable thermostat located in the workstation area shall control the environmental control unit
- f) Provide an Uninterruptible Power Supply (UPS) capable of sustaining safety-critical and flight-critical operations for one hour minimum
- g) Include suitable mounting hard points for mounting three TBD foot extendable masts and pneumatic controls
  - the TBD foot extension mast shall extend at least 30 ft above the top of the vehicle when fully extended.
- h) Have an external spotlight assembly at each corner of the enclosed box (work area)

Figure 2.2-1 shows one possible layout of a MOS vehicle.



**Figure 2.2-1 Candidate MOS Vehicle Layout**

### 2.2.2 Operations Engineer Station

The Operations Engineer will be responsible for overseeing and monitoring the operation of the various MOS research hardware systems prior to and during GTM flight test activities. The Operations Engineer shall:

- Provide for monitoring of, control of and physical access to MOS research hardware systems
- Provide displays that will provide system status parameters, states, and appropriate health parameters for MOS hardware systems
- Provide access to all computer generated displays and video camera outputs available during research flights (e.g. TD, SD, nose camera video)
- Provide for audio communication with any other flight test participants deemed necessary

### 2.2.3 Safety Pilot Station

#### 2.2.3.1 System Description

In recognition of the fact that research flight will be increasingly dynamic in nature and will seek to set up high-risk/off-nominal (e.g. large angle-of-attack and sideslip) flight conditions it is deemed necessary to retain the role and inputs of a conventional R/C pilot towards enhancing overall mission safety. This capability to host a secondary controller, hereby termed the safety pilot, shall have the following attributes:

- a) The safety pilot shall be located externally to the MOS vehicle to provide a line-of-sight view of the GTM so as to afford direct observation of craft attitude and to eliminate risks associated with indirect viewing due to video hardware failure
- b) The safety pilot inputs shall originate from a conventional handheld R/C transmitter that shall be configured to continuously emanate a special safety channel signal
- c) Provision shall be made for isolated two-way audio communication with the Flight Test Director Station and the Research Pilot Station
- d) The avionics of the GTM craft shall be engineered to receive the safety channel signal for the purpose of discriminating amongst three flight control cases:
  - ground research pilot inputs for advanced/general experiment conditions
  - ground safety pilot inputs for basic/aborted experiment conditions
  - onboard range-safety inputs (until a suitable return-to-home autopilot is integrated into the ship system) for abnormal/terminated flight conditions

#### **2.2.3.2 System Performance**

The MOS vehicle shall provide a small deployable station for the external safety pilot and shall drive its interface in order to provide the following features:

- a) This station shall be based around an adjustable three-legged camera-style tripod so as to provide a stable heavy-gauge yet compact and movable support for hosting the necessary electrical equipment near the flight line at a convenient height level
- b) Topping the mast of this tripod shall be a monitor providing a switchable display of nose or tracker camera video. This monitor shall be equipped with an outdoor viewing hood for the shedding of extraneous interfering light
- c) Attached to this tripod shall be an intercom loop junction box with headphones providing two-way communications with the MOS system
- d) Either installed to this tripod or to the MOS vehicle itself shall be a secondary R/C receiver providing ground confirmation of safety transmitter operation. This receiver shall deliver at a minimum an output of the safety channel PCM signal for the purpose of providing positive indication of flight control mode
- e) This tripod shall host a cable for providing a suitable external power feed to the safety transmitter for minimizing risk due to failed batteries within the transmitter.
- f) A portable windsock or other wind direction indicator shall be included

#### **2.2.4 Differential GPS Ground Reference System**

Differential GPS position corrections will be required for uplink to the airborne GTM. A system to provide DGPS shall consist of a separate GPS receiver that can provide pseudorange corrections, and this correction data is interfaced to the MOS ground computing and TM systems.

### **2.2.5 MOS-to-BRS Audio/Video Communications**

The capability to transmit near-real-time voice, sensor and video data from the MOS to the BRS is required. The capability to receive voice and near-real-time data from the BRS to the MOS is required. This capability will allow researchers at LaRC to monitor and participate in remote flight tests without traveling to the remote site. The MOS-to-BRS data link should accommodate near-real-time transmission of 100 channels (parameters) of data at 20 samples/sec. Near-real-time video will be the tracking video and selectable between the nose-camera and Flight Line video camera outputs.

### **2.2.6 Video Tracking System**

#### **2.2.6.1 System Description**

In order to provide the capability to monitor the GTM in flight, a ground-based video tracking system will be deployed with the MOS and will track the airborne vehicle using cameras and electronic equipment. This video tracking system will be augmented by a wireless video and audio transmission system, to provide for transmission of tracking video and voice communications from the video tracking system to the MOS. This system shall be setup at a location within a radius of 2 statute miles and within line-of-sight of the MOS wireless video receiver. This location will be called the Tracking System Station (TSS). An operator shall be required to operate the system. The TSS shall have a two-way communication link to the Flight Test Director Station. The tracking system shall be capable of receiving GTM GPS/DGPS position data in order to augment the system's ability to maintain GTM tracking lock (ref section 2.2.8). The tracking video shall be transmitted to the MOS (ref section 2.2.7.2) for display as desired by users at the various operations stations.

#### **2.2.6.2 System Performance**

The GTM Video Tracking System shall meet or exceed the following performance requirements. The GTM Tracking System shall:

- a) Be a fully portable and self-contained system, capable of being transported in a maximum of four travel cases, with each case having a maximum allowable weight of 120 pounds.
- b) Be comprised of a portable pier tripod assembly, supporting video acquisition and capture hardware mounted on a motorized 2-axis gimballed system
- c) Operate from 110-120VAC (220 VAC, or 18 VDC with additional power supply)
- d) Incorporate a closed-loop DC servo motor control system
- e) Provide built-in power conditioning for all electronics
- f) Include an Automated Telescope Startup Unit (ATSU) with precision home and park positions to .001 degrees, with electronic Periodic Error Correction (PEC) and CCD port for astronomical self-guiding

- g) Be capable of computerized full-sky "Go-To" pointing, which can be set up for remote or local operation
- h) Be capable of equatorial and alt-azimuth alignment and tracking, with adjustable slew speeds up to 6.0 degrees per second
- i) Be delivered with source code for acquisition and tracking software applications
- j) Provide for integration of target GPS/DGPS position data in order to augment the system's ability to maintain tracking lock

## **2.2.7 Wireless Video Transceivers**

### **2.2.7.1 System Description**

The MOS will be required to receive and distribute the outputs of several video cameras. Currently three video sources have been specified and include (1) Tracking System, (2) GTM Nose Camera and (3) Flight Line Camera. Video from the source cameras shall be transmitted to the MOS via wireless transmission systems. The received video shall be distributed as necessary.

#### **2.2.7.2 Tracking System Video Wireless Transceiver**

The Tracking System wireless transmission system shall:

- a) Provide for digital video transmission over license-free wireless frequency bands
- b) Deliver MPEG-3 or MPEG-4-based video at a minimum rate of 30 frames per second (fps) over a minimum distance of 3 statute miles
- c) Support operating with multiple wireless networks while providing security, reliability and high tolerance to interference
- d) Be built on open standards

#### **2.2.7.3 GTM Nose Camera Video Wireless Transceiver**

The Nose Camera wireless transmission system shall:

- a) Provide for analog video transmission over licensed wireless frequency bands.
- b) Deliver standard NTSC composite video at 30 frames per second (fps) over a minimum distance of 1 statute mile.
- c) Operate in conjunction with onboard telemetry uplink/downlink without causing data interference.

#### **2.2.7.4 Flight Line Camera Video Wireless Transceiver**

The Flight Line Video wireless transmission system shall:

- e) Provide for digital video transmission over license-free wireless frequency bands
- f) Deliver MPEG-3 or MPEG-4-based video at a minimum rate of 30 frames per second (fps) over a minimum distance of 1 statute miles

- g) Support operating with multiple wireless networks while providing security, reliability and high tolerance to interference
- h) Be built on open standards

## **2.2.8 Wireless Data (GPS) Transceiver**

### **2.2.8.1 System Description**

The MOS will be required to transmit GTM GPS/DGPS position data to the TSS in order to augment the tracking system's ability to maintain GTM tracking lock (ref section 2.2.6). The MOS shall utilize a wireless data transmission system to provide GTM GPS data to the TSS.

### **2.2.8.2 System Performance**

The wireless data transmission system used to provide GTM GPS data to the TSS shall:

- a) Provide a complete wireless solution for serial communications without a FCC license
- b) Provide reliable data transfer at a minimally acceptable baud rate range of 2400 to 115200 baud, over line-of-sight distance of at least 3 statute miles.
- c) Provide built-in error detection and error correction to ensure data accuracy
- d) Support operating with multiple wireless networks while providing security, reliability and high tolerance to interference

## **2.2.9 Audio/Video Systems**

### **2.2.9.1 Audio System Description**

The MOS shall provide the communications infrastructure to allow all key participants in GTM flight test activities to maintain voice contact. The MOS audio communications system shall:

- a) Provide isolated two-way audio communication between the Flight Test Director Station and the R/C Safety Pilot Station
- b) Provide the Flight Test Director Station with master access control capability for voice communications
- c) Employ the use of headsets with push-to-talk capability

### **2.2.9.2 Audio System Performance**

- a) The MOS audio communications system shall be capable of accommodating two-way voice communications between the following:
  - Flight Test Director
  - Research Pilot
  - Researcher
  - TSS operator

- Safety Pilot
  - Operations Engineer
  - BRS
- b) The MOS audio communications system shall accommodate inclusion of at least one additional internal and one additional external voice communications interface.

### **2.2.9.3 Video System Description**

The MOS shall provide the video hardware infrastructure to allow all video camera output signals and all computer generated displays to be amplified and split as necessary for distribution to key participants in GTM flight test activities. The MOS video system shall:

- a) Provide users at the Flight Test Director's Station, Research Pilot's Station and Researchers Station the capability to route any video source image to any desired display monitor at the respective station.
- b) Provide for time-synchronized recording and playback of all video images with all other GTM flight test data.
- c) Provide for delivery of Tracker video and GTM Nose Camera video to BRS in near real-time during flight test activities

### **2.2.9.4 Video System Performance**

- a) The MOS video system shall, at a minimum, support amplifying, splitting, distributing and recording video signals meeting the primary consumer video standards including, but not limited to:
  - National Television System Committee (NTSC)

## **2.2.10 Internet Accessibility**

### **2.2.10.1 System Description**

The MOS shall provide for access to the internet in order to retrieve useful data including, but not limited to:

- a) Real-time weather radar images
- b) Real-time weather forecasts

The MOS shall provide additional internal and external internet access points

## **2.2.11 Portable Weather Station**

### **2.2.11.1 System Description**

In order to provide pertinent weather data to GTM pilots and flight test managers, the MOS shall incorporate a portable weather station. The weather data shall be delivered to the Flight Test Director Station. The portable weather station shall include software and data ports such that from the Flight Test Director Station, the weather data can be interfaced to a stand-alone

PC (Personal Computer), from which desired weather data can then be accessed by the Pilot Station and Researcher Monitor Station.

#### **2.2.11.2 System Performance**

- a) The data provided by the MOS portable weather station shall include, but not be limited to:
  - Wind speed
  - Wind direction
  - Wind chill
  - Barometric Pressure
  - Outside temperature
  - Inside temperature
  - Outside relative humidity
  - Inside relative humidity
  - Dew point
  - Heat Index
  - UV radiation index
  - Sunrise/sunset
  - Time clock
- b) The portable weather station shall provide for setting threshold alarms for wind, barometric pressure and temperature parameters.
- c) The portable weather station shall provide trend indicators for barometric pressure.

### **2.3 BRS-Specific Requirements**

#### **2.3.1 BRS-to-MOS Audio/Video Communications**

The capability to receive real-time voice, sensor and video data from the MOS in the BRS is required. The capability to transmit voice and near-real-time data from the BRS to the MOS is required. This capability will allow researchers at LaRC to monitor and participate in remote flight tests without traveling to the remote site. The BRS-to-MOS data link should accommodate near real-time transmission of 100 channels (parameters) of data at 20 samples/sec.

#### **2.3.2 Satellite-based Data/Video Link**

##### **2.3.2.1 System Description**

In order to provide the capability to monitor MOS GTM flight test activities at the Base Research Station located at Langley Research Center, a satellite backbone transmission system will be utilized to (1) transmit GTM telemetry state data, optical video and voice communication from MOS to BRS, and (2) transmit desired support data and voice communications from BRS to MOS. The major communications system elements comprising

the satellite system consist of a fixed base station satellite dish, a deployable remote station satellite dish, and the necessary interface equipment. The Base and Remote Stations employ a satellite backbone transmission system augmented by data, video and voice communication facilities, and an Internet Protocol (IP) routing system. The IP routing system provides for multiple communication transmission types and automatic routing path requirements. The base station consists of a 2.4 - meter dish antenna and rack mounted satellite, video, audio, and routing equipment. The remote station consists of a 1.2-meter dish antenna contained in two field carrying cases, a field case for the antenna RF equipment, and satellite, video, audio, and routing equipment mounted in a separate field carrying case. The remote station is further augmented by a wireless video and audio transmission system, which provides for line of sight transmission of tracking video and voice communications from the TSS (reference section 2.2.3). The satellite system will rely on an Immeon network communications link. The Immeon System is a joint venture between Loral Skynet and ViaSat. The Immeon System is unique in that it can supply connectivity between satellite stations via a satellite, in this case Telstar IV, on an as need basis. This lowers satellite usage costs. The connection service is available on a 24 hours-per-day, 7 days-a-week basis and is provided by a teleport and network control system located in Atlanta, GA. The system communications are based on Internet Protocol (IP) addressing; fully automating all routing of video, data, and voice communications within the system. This is accomplished by using commercial off-the-shelf network routing equipment. The routing equipment will utilize telephony- switching equipment to accommodate voice communications. The camera optical data will be processed by a video encoder at the MOS site for satellite transmission, and translated back to video at the BRS site for display purposes.

#### **2.3.2.2 Radio Frequency Authorizations**

The satellite system will utilize two carrier frequencies within the U.S. Ku band, between 14.0 and 14.5 GHz. The LaRC Spectrum Manager has granted authorization to the GTM project to use these frequencies. As this frequency is in a non-federal government band, it was coordinated through the Federal Communications Commission (FCC) and is subject to FCC jurisdiction. Consequently, there is a one-year duration of use with renewal options. Authorization will come under review annually for continued use, and is subject to immediate cancellation upon notice from the FCC. Refer to Radio Frequency Authorization: NASA032003.

#### **2.3.2.3 System Performance**

The 2.4Meter fixed dish at the BRS will employ an 8Watt power amplifier to achieve a 1.0Mbps uplink data rate. The 1.2Meter deployable dish at the MOS will employ a 25Watt power amplifier to achieve a 2.048Mbps uplink data rate.

#### **2.3.2.4 System Limitations**

As the Telstar IV system is comprised of satellites located 22,000 miles above the equator in geosynchronous Earth orbit, closed-loop operations involving GTM control inputs generated at the BRS will incur a 0.5sec (minimum) latency. For this reason, remote piloting of the GTM from the BRS will not be attempted.

### ***2.3.3 Interface to SAFETI Lab Research Systems***

The BRS shall provide the capability to integrate GTM TM data and video into the research facilities comprising the SAFETI Lab.

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